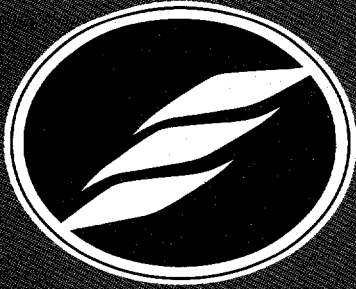


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**Issues for Reuse of
Gloveboxes at LANL TA-55**

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Issues for Reuse of Gloveboxes at LANL TA-55

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Published August 1998

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Defense Program Environmental Surety Program
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ABSTRACT

This report is a summary of issues that face plutonium glovebox designers and users at the Los Alamos National Laboratory (LANL) Technical Area 55 (TA-55). Characterizing the issues is a step in the task of enhancing the next generation glovebox design to minimize waste streams while providing the other design functions. This report gives an initial assessment of eight important design and operation issues that can benefit from waste minimization.

EXECUTIVE SUMMARY

This report is a summary of the issues that face plutonium glovebox designers and users at the Los Alamos National Laboratory (LANL) Technical Area 55 (TA-55). An initial assessment of waste streams from the glovebox confinement system has been performed, and a review of the issues that are related to pollution prevention has been carried out. LANL personnel have shared a comprehensive list of design issues that are important to operability, safety, and reusability of gloveboxes. They also added to this assessment by focusing on eight issues important to the next generation glovebox design. These eight issues are also pollution prevention issues that LANL personnel believe are the most important for improving glovebox reuse, waste reduction, and operational efficiency. The eight issues fall into four categories:

- separating chemically hazardous waste (i.e., lead shielding) from the radiological waste of a decommissioned glovebox
- plutonium contamination control during operations and decommissioning
- decontamination of gloveboxes for reuse or disposal as low level waste
- ergonomics for operations personnel.

This report describes these issues and current LANL practices, to support an engineering survey study that will address alternatives to meet or solve the eight issues. An initial assessment of these eight areas where the Idaho National Engineering and Environmental Laboratory (INEEL) can support LANL has been performed and is reported here. This assessment is a precursor to an engineering survey study of alternative solutions that will be released later in the year.

ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AGS	American Glovebox Society
ALARA	as low as reasonably achievable
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
B	Boron
Bi	Bismuth
Bq	becquerel
cm	centimeter
D&D	Decontamination and Decommissioning
DOE	Department of Energy
DP	Defense Programs
EPA	Environmental Protection Agency
Er	Erbium
ES&H	Environment, Safety and Health
°F	degrees Fahrenheit
HEPA	high efficiency particulate air filter
IAEA	International Atomic Energy Agency
INEEL	Idaho National Engineering and Environmental Laboratory
LANL	Los Alamos National Laboratory
LLW	low level waste
MCS	Modular Containment System
NFPA	National Fire Protection Association
NRC	Nuclear Regulatory Commission
OR	Occurrence report
ORPS	Occurrence Reporting and Processing System
PP	pollution prevention
Pb	lead
PF-4	Plutonium Facility building at TA-55
PMMA	polymethyl methacrylate
psi	pounds per square inch
Pu	plutonium
SS	stainless steel
Sv	sievert
Ta	Tantalum
TA	Technical Area at LANL
TRU	Transuranic

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Issues for Reuse of Gloveboxes at LANL TA-55

1. INTRODUCTION

The work described in this report supports the Idaho National Engineering and Environmental Laboratory (INEEL) Defense Programs (DP) Environmental Surety Program. This program has been established to design and build waste analytical tools and instruments, waste handling, and treatment systems for use at various DP Laboratories and sites, with current emphases at the Los Alamos National Laboratory (LANL). This project performs work as part of a Memorandum of Agreement [1] signed by the Department of Energy (DOE) Albuquerque and Idaho Operations Offices. The Redesign of Glovebox Project in this program entails performing a pollution prevention (PP) study on identified areas that cause the biggest obstacle to glovebox reuse. After identification in this report, these areas of concern will be researched in an engineering survey, and a report will be issued to document potential solutions to these problems.

The TA-55 Plutonium Facility at LANL performs basic and applied Special Nuclear Materials research to develop and demonstrate technology, and to provide production support for national defense and specialized energy programs. The Plutonium Facility (PF-4) is an integral part of TA-55. PF-4 became operational in April 1978, and uses hundreds of gloveboxes to confine various experiments and other processes. Figure 1 shows a sketch of a typical glovebox that might be found at PF-4.

The request by DP for a PP study, as documented in Reference [1], is part of the implementation of DOE policy to reduce the volume of radiological and hazardous waste that must be disposed of [2]. In response to the request, the Idaho National Engineering and Environmental Laboratory (INEEL) began a study to analyze the life-cycle operations and associated costs of the glovebox life cycle, from design and manufacture to disposal. This study is possible only with the collaboration of LANL personnel. The study specifically addresses the possibility of developing a single design for standardized gloveboxes, the replacement of lead (Pb) with some other radiation shielding material, the potential for recycling gloveboxes, the ease of radiological cleanup and decontamination of gloveboxes, and the need to reduce costs in all phases of the glovebox operating lifetime. The single, standardized glovebox design has technical concerns; these are discussed in Appendix A. A PP study focuses on reducing the volume of the various wastes (solid, liquid, or gas wastes) associated with glovebox use and disposal, and on the use of time and resources. Reducing the waste volume reduces the likelihood of pollution of air, water, and soil, and it reduces the cost and effort associated with waste disposal. Efficient use of time and resources reduces the production of waste. Note that the PP study examines the waste streams associated with the glovebox containment systems themselves, not the materials handled inside the gloveboxes.

This report documents work by INEEL researchers in performing the first part of the study, which consists of identifying and evaluating the relevant issues. This effort builds on past efforts by TA-55 personnel to identify waste streams and reduce waste

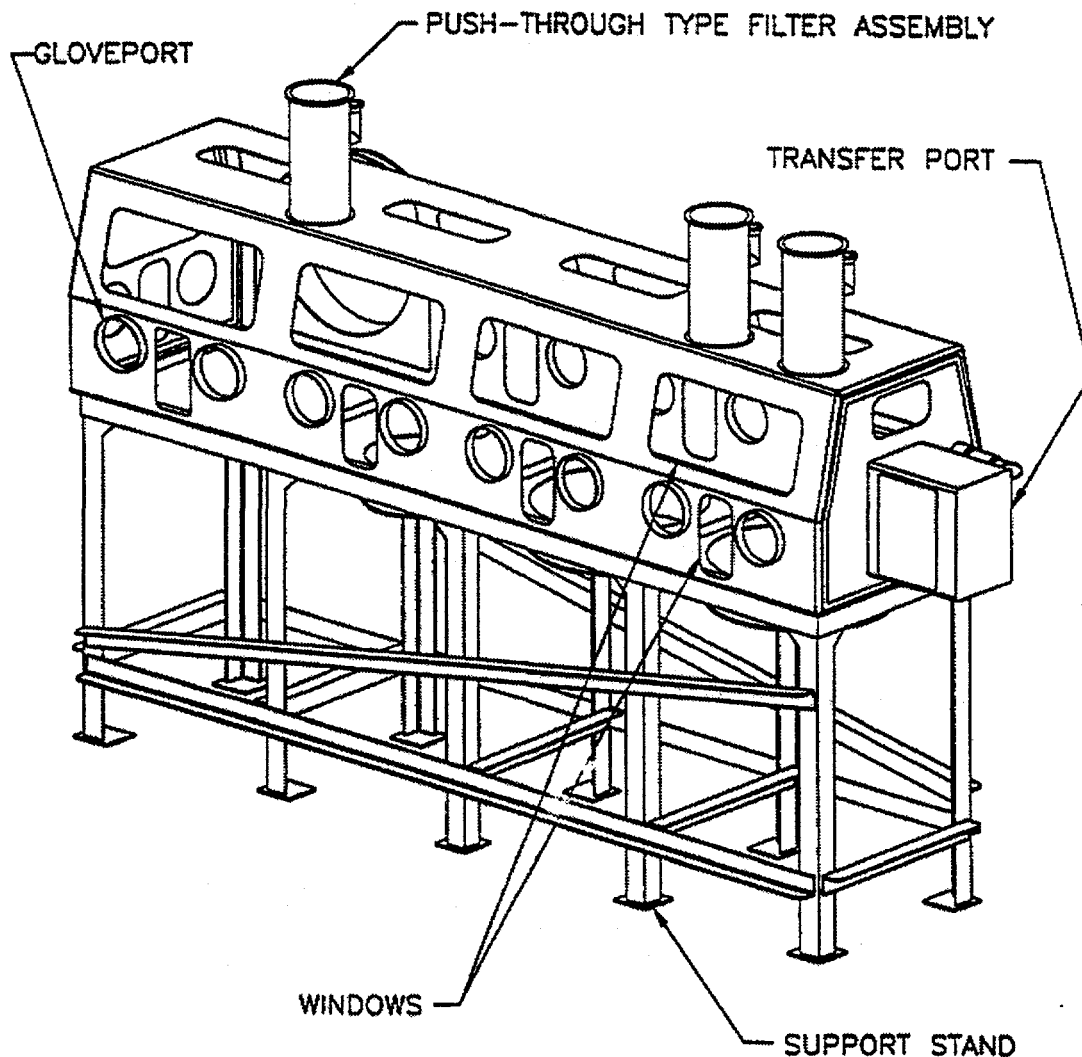


Figure 1. Sketch of a typical glovebox
(from American Glovebox Society, report AGS-G001-1998).

volumes (see Reference [3], for example), and it relies on collaboration with, and support from, the TA-55 personnel involved in the PP study. This report identifies waste streams associated with glovebox operation and disposal (Section 2), specifies glovebox reuse issues (Section 3), reviews pertinent literature (Section 4), and presents a preliminary analysis of the issues (Section 5). The information provided in this report will prove useful to INEEL engineers whose task it will be, in a later phase of this glovebox redesign task, to propose design improvements for gloveboxes to minimize the waste associated with their use, decontamination, reuse, and disposal.

2. WASTE STREAMS

Waste streams were identified by inspecting gloveboxes for all inputs and outputs during a tour of several rooms in PF-4. A control volume analysis approach was used. In this control volume analysis, all flows across the boundary of the glovebox are identified; if they are waste streams, they are counted. Information provided by personnel at TA-55 was reviewed, as well as pertinent literature on decommissioning processes.

Table 1 lists the identified waste streams associated with glovebox containment systems during operation and decommissioning. Relevant issues of time and financial resource efficiency, also part of this PP study, are included in the list in Table 1. These identified waste streams, combined with the insights from LANL personnel, form the basis for selecting issues to survey in this glovebox design enhancement task.

Table 1. Glovebox Waste Streams

Glovebox solid wastes from routine equipment replacement

Gloves
Gaskets
High efficiency particulate air (HEPA) filters
Filter media for liquids (i.e., demineralizer resins and other filters)
Light bulbs from in-glovebox lights (rarely used at TA-55)
Plastic bag material and adhesive tape from "twist and tie" bagout operations
Cloths, wipes from periodic in-box cleaning
Windows (infrequent - perhaps once - need for replacement during box service life)
Worn out tools from the glovebox processes (e.g., saw blades, drill bits, worn hand tools, and other consumable items)

Glovebox solid wastes generated during decommissioning

Glovebox shell, radiation shielding, filter housings, and gas flow control dampers
Glovebox piping for gas atmosphere and services (coolant, etc.)
Glovebox instrumentation (pressure sensor, fire detectors, criticality alarm, etc.)
Glovebox overpressure relief device and in-box fire suppression system piping
Glovebox service connections (electric and gas panels, etc.) and maintenance ports
Glovebox transfer tunnel connector rings, gaskets
Glovebox windows, gloves, gaskets, gas filters

Glovebox liquid wastes generated during operations or decommissioning

Coolants for processes in the glovebox, such as water
Cleaning and decontamination liquids (such as Fantastik® cleaner, water, etc.)
Bubbler (overpressure relief device) liquid

Glovebox gas wastes generated during operations

Atmosphere treatment creates gaseous wastes (and solid wastes) in filters
 Cleansing the inert gas (such as argon) that flows at perhaps 5 atmosphere changes per glovebox per hour
 Cleansing the air that flows at perhaps 7 air changes per glovebox per hour
Gaseous coolants, such as freon, for cooling high temperature in-box operations

Time efficiency during operational tasks

Operator time per process task may be increased when glovebox designs are not preplanned for ease of use to accommodate material handling concerns
Operator ergonomic issues may force frequent rest breaks, decreasing productivity and raising ergonomic concerns over manual material handling
Operator time used for contamination control, rather than process tasks
Operator error rate depends on human engineering factors, such as appropriate view and lighting, equipment labeling (valves, etc.), and clear task instructions

Table 1. Glovebox Waste Streams (continued)

Economic resource efficiency in operations

Excess power use to operate the glovebox (lighting, fan power to flow gas) are costly

Enhance glovebox unit longevity to avoid replacement before the end of useful life

Standard glovebox design that accommodates multiple applications

Economical decontamination of gloveboxes for reuse

Note: These waste streams originate from the glovebox confinement system, not the process housed within the glovebox. For decommissioning, the process equipment within the glovebox must also be decontaminated and removed, but that equipment is generally process-specific and is not considered here.

3. GLOVEBOX REUSE ISSUES

The personnel at TA-55 developed an exhaustive list of issues important to the design and operation of next generation of gloveboxes, both new facility design and for designing modifications to existing processes at TA-55. These issues are presented in Table 2, with criteria rankings based on conversations with TA-55 personnel and knowledge of glovebox design and operation. The list of categories and issues is quite broad, spanning design, safety, operations, and pollution prevention issues. This PP study does not attempt to address all of these issues, but instead focuses on pollution prevention and related redesign issues, thus limiting the work scope to a task that can provide meaningful results with the available resources.

In June 1998, TA-55 personnel gave INEEL a list of nine issues that they found to be the most important issues not currently under study at LANL. These are issues toward which LANL has not yet devoted research resources; issues that still need to be resolved in a cost-effective, satisfactory manner. Workable solutions already exist for some of these issues, but those solutions are generally not cost-effective, and they potentially generate more waste than optimized solutions. These nine issues are:

1. Research ways to improve glovebox longevity and significantly extend service life.
2. Investigate substitution of some other material for lead used in the radiation shielding sandwich on the glovebox exterior. Perhaps develop some means to remove the lead at the end of the glovebox service life.
3. Improve the service life of window gasket seal, and identify a better way to install replacement windows.
4. Reduce leakage through glovebox wall penetrations and feedthroughs.
5. Control contamination when glovebox connector flange spool rings are removed, and search for a flange connector ring that controls contamination better than existing designs.
6. Remove sharp internal corners in the design of gloveboxes to make them easier to decontaminate.
7. Identify a better stainless steel sheet surface finish than the 2B Finish for ease of decontamination.
8. Evaluate ergonomic enhancements for glovebox operators, the issues of working in glove ports at various heights and gloves of various thicknesses, and with the gloveboxes of various widths.
9. Identify a standard light that will provide better localized in-box illumination with the current window configurations.

Table 2. Glovebox design issues for the next generation design.

LANL Issues	Issue review criteria				
(An asterisk * indicates that LANL is already working on this issue)	Complete a study in 6 mo.	Method to accomplish	Degree of problem	Pollution prevention issue	Pervasiveness of issue
<p>Glove issues</p> <ul style="list-style-type: none"> - push thru gloves* require 9-in diameter port, this adds manufacturing time - new glove design* use Bi/Er or Ta/B for radiation shielding; devise glove wear indicator; improve wear resistance - Should there be specifications for all DOE gloves? - glove transponders* to track gloves for replacement 	yes, to a subtask	see notes	high	yes, waste & contam. control	high, all boxes use gloves
<p>Bag-out port issues</p> <ul style="list-style-type: none"> - contamination potential - puncture by sharps - fire susceptibility - collection point for solutions 	yes	see notes	assume moderate may be high	yes, contam. control and waste of bags	moderate to high, a few boxes do not use bag outs
<p>Gas flow cleanup</p> <ul style="list-style-type: none"> - halide poisoning in gas cleanup beds 	yes	see notes	assume high	yes, reduce waste of resins	moderate some boxes do not use inert gas
<p>Review gasket recipe</p> <ul style="list-style-type: none"> - neoprene elastomer breaks down under irradiation 	yes	see notes	assume moderate to high	yes, contam. control	high, all boxes have gaskets
<p>Shielding (fixed vs portable)</p> <p>and</p> <p>Shielding (replace lead as a shielding material)</p>	yes on fixed vs portable, maybe on replacing Pb	see notes	assume high	yes, disposal cost issue to separate waste streams	high, all Pu-239 boxes need shielding for low energy gamma rays

Table 2. Glovebox design issues for the next generation design (continued).

LANL Issues	Issue review criteria				
(An asterisk * indicates that LANL is already working on this issue)	Complete a study in 6 mo.	Method to accomplish	Degree of problem	Pollution prevention issue	Pervasiveness of issue
Box penetrations - penetration leakage - connector sizes and shapes - options for service line connections - introductory ports - introduction panels	yes	see notes	assume moderate may be high	yes, contam. control	high, all boxes have penetrations
Box doors - failed cables - failed u-clamps	yes	see notes	assume moderate may be high	yes, contam. control	moderate some boxes have doors
Reagent transfer device - keeping external surfaces of containers uncontaminated	yes	see notes	assume moderate	yes, contam. control	moderate some boxes have reagent
Contamination control - containment must balance with ease of manufacturing and ease of operations - atmosphere containment - Is kynar lining the best liner available for a corrosive environment? - Meeting safety requirements for gloveboxes that draw in air? - HEPA filter spacers, SS or plastic? - Inert boxes use NI-train or DRI-train, sometimes get poisoned - glovebox atmosphere	yes, to an issue	see notes	assume moderate may be high	yes, contam. control	high, contam. is an important health and safety issue

Table 2. Glovebox design issues for the next generation design (continued).

LANL Issues	Issue review criteria				
(An asterisk * indicates that LANL is already working on this issue)	Complete a study in 6 mo.	Method to accomplish	Degree of problem	Pollution prevention issue	Pervasiveness of issue
Leak testing of contaminated boxes - Helium must migrate against the pressure difference to keep the detector uncontaminated	no, very involved issue, take longer than 6 months	--	assume high, LANL enthused during 04/28/98 call	yes, contam. control	high, no boxes are leak checked after commissioning
D&D issues - ease and degree of cleaning* - evaluate why the 2B surface finish decons better than other surface finishes at LANL	yes	see notes	assume moderate to high, polishing box is a minor task	yes, disposal costs, wastes generated	high, LANL has a concern about D&D
Life cycle costs - Manufacturing thru disposal - Specs for all DOE gloveboxes?	no, not enough resources for detailed study	--	assume high	yes, cost issue	high
Glovebox ergonomics - visibility vs window size - height vs reach and ease of use in gloves - accommodate worker heights - gloves - hand fatigue - lighting in gloveboxes	yes	see notes	assume moderate The boxes do function the way they are.	yes, time efficient operation issues	high, all boxes have some 'ergo' issues
Earthquake restraints - weight and stability - support frames - anchors	yes	see notes	assume moderate to minor	no, safety issue	high, all boxes need anchors
Fire and explosions - gloves are combustible - gaskets are combustible, serve as pressure relief point - windows break under stress	yes	see notes	assume moderate to minor, event frequency is 0.01 or lower /yr	yes, contam. control, and waste generator	moderate not all boxes will have same hazard potential
Conveyor system - corrosion of rails in aqueous area	no, will take longer than 6 months	--	assume moderate	no, operation safety	High, conveyor is important to TA-55

Table 2. Glovebox design issues for the next generation design (continued).

LANL Issues	Issue review criteria				
(An asterisk * indicates that LANL is already working on this issue)	Complete a study in 6 mo.	Method to accomplish	Degree of problem	Pollution prevention issue	Pervasiveness of issue
Box service lines - filter protection on gas lines vs control of gas flow direction	no, will take longer than 6 months	--	assume moderate	yes, contam. control	high, most boxes need services
Solutions in box - pencil and slab tanks for criticality control	no, will take longer than 6 months	--	assume moderate	no, process control and process safety	moderate some boxes will require solutions
Glovebox size - wells, blisters, and extra height versus standard design	yes	see notes	minor	no, design and operation issue	small, only a few boxes affected
Conductivity rating on gloves - electrical safety for operator	yes	see notes	minor to moderate	no, safety issue	moderate some in-box tools, etc. use electricity
Support frame qualification - seismic qualification	yes	see notes	high	no, safety issue	high, all boxes have a frame
Review of water cooling - contamination in cooling water	no	--	moderate	yes, contam. control	moderate some boxes are cooled
A substitute window material for Lexan that is less of a fire load - window material will burn	yes	see notes	moderate to minor	no, fire safety issue	high, most boxes use Lexan or PMMA

Notes: Some methods to accomplish the studies are:

- Literature review for materials use in glovebox design
- Literature review for operating experiences in similar work environments
- Literature review for industrial best practices information
- Vendor visits, product reviews
- Testing options or potential solutions to problem
- Hardware development
- Full implementation of hardware in the field for a trial period

The list of nine important items compares favorably with the waste streams identified in Table 1. Shielding and seals are decommissioning waste streams. Contamination control is an important waste control issue (cleaning up surfaces uses more materials, such as cloths, gloves, etc. that generate waste, and uses operator time). Decontamination is an important glovebox reuse issue, a necessary step to allow personnel to set up a new process within the glovebox. The last two are ergonomic issues that relate to time efficiency and productivity issues, where operators are taken into consideration. All of these issues are part of a pollution prevention study. Since these items are the LANL issues of interest for near-term upgrades or future glovebox designs and they are all part of pollution prevention, they are the focus of this glovebox design enhancement study. The first of the nine issues is a broad statement addressed by some of the other listed issues. All of the other eight issues listed above have technical bases. The technical bases for these eight issues are discussed below. The information on LANL issues comes from discussions with LANL personnel via on-site meetings, telephone calls, electronic mail exchanges, and published literature review.

Lead shielding sandwich on the glovebox exterior

The use of lead shielding for gamma rays is widespread and well known. Lead has excellent shielding properties due to its high density (11.3 g/cm^3), its mass attenuation coefficient ($7.8 \text{ cm}^2/\text{g}$ at 50 keV gamma energy), and its ease of fabrication [4]. Thin sheets of lead suffice for adequate radiological protection. The difficulty is in disposal of the lead. Due to concerns that the US Environmental Protection Agency (EPA) has had regarding ingestion of lead (e.g., workers being exposed to lead aerosols during painting, building construction, battery fabrication, etc.), 40CFR261 makes lead part of the EPA hazardous wastes in the Resource Conservation and Recovery Act. Elemental lead and lead oxides are included as hazardous waste D009. This designation increases the disposal costs of the glovebox because the combination of solid lead shielding material and some radiological contamination means that the glovebox is a mixed waste (i.e., toxicological and radiological waste). LANL has investigated using other materials for shielding [5]. Other materials, such as simply using thicker stainless steel for the glovebox wall, means thicker walls and heavier gloveboxes (a stainless steel wall 3 times the lead thickness or more). A typical glovebox at LANL has a 0.1875 inch thick (7 gauge) 304 or 316 stainless steel wall, then a 0.25 inch thick lead sheet, then a sandwich cover of 0.0625 inch-thick stainless steel. For a no-lead shielding option where the stainless steel is three times the lead thickness or more, the total glovebox thickness would be at least 0.9375 inches, which is a much more difficult thickness to bend to shape, especially the corners. Corner construction is important; well fit corners eliminate crevices where contamination could lodge. Companies that can perform fabrication of thick-walled gloveboxes are few, meaning increased costs and longer construction times.

TA-55 personnel have also investigated the use of air chisels to remove the lead shielding from a radiologically uncontaminated glovebox (a box that was never used in the plutonium line, but was being decommissioned). The first effort was not as promising as they had hoped, but it is possible that using different equipment might improve the removal of the steel skin and the lead beneath.

TA-55 personnel also investigated the use of lead shielding aprons. These aprons are thin sheets of lead, clad on both sides with a thin sheet of stainless steel. The aprons were intended to hang on the outside of gloveboxes. They would be removable, so that when a glovebox was decommissioned, the apron would be removed and used on some other glovebox. The concern with the possibility of contamination spread outside the glovebox meant that both sides of this apron, and the glovebox walls, would have to be decontaminated. Handling a heavy apron for decontamination was a concern. Another concern included seismic stability of the aprons and hangers. This idea for reusable shielding was not pursued any further.

Window gasket seal material and lifetime

There are two types of window gaskets used at LANL TA-55. One is the so-called 'zippered' window that uses a channeled neoprene gasket and a spline (a rope-like neoprene insert that fits into the channel in the gasket) that compresses the gasket slightly to make the gasket bind tightly around the edge of the window and the glovebox opening. While this gasketing system is not as robust as a framed window, pressure tests of early gloveboxes showed that 20 inch by 30 inch windows withstood a pressure difference of 24 inches of water. [6] LANL gloveboxes typically operate at about -0.6 inch of water relative to the room atmosphere. The other type of gasket is a flat neoprene gasket used in a bolted window frame; this gasket is in compression between the glovebox shell and frame. The zippered windows have not functioned as well as the bolted windows from the aspect of gasket life or leakage [7]; however, the zippered window gloveboxes are less expensive to manufacture, since there is no need to weld bolt stems to the glovebox wall. When the number of windows on a glovebox is considered (two windows per operator station, ceiling windows for lighting), the capacitor discharge welding technique to fix the bolt stems to the glovebox surface can add to the cost of the glovebox. As a crude estimate, at a half person-day per window, a moderate size 6-station, two deck glovebox with 20 windows could result in perhaps an additional 10% to the glovebox total manufacturing cost. The zippered windows are probably less time consuming from a maintenance perspective as well, saving the time of unbolting and then retorquing two dozen bolts per window while maintaining contamination control.

The neoprene gaskets [8] have not stood up well to the radiation environment in the gloveboxes that confine Pu-238 oxide. Pu-238 can decay by both alpha particle (5 MeV range) and gamma ray (40 keV range) emissions, and it has a relatively high spontaneous fission rate that results in neutron emission as well. Also, Pu-238 alpha particles can interact with the oxygen in the oxide, leading to oxygen (α, n) reactions. While spontaneous fission neutrons are born at around 2 MeV, these (α, n) neutrons have higher energies that can lead to more degradation of gaskets. When the neoprene seal degrades by radiolytic decomposition or other degradation, then the glovebox is no longer a good confinement boundary. Contamination may migrate out past the seal, or any released liquid in the glovebox that impinges on the seal might leak past the seal. Either case is not healthy for the operators, since they are exposed to direct radiation and possibly to airborne, inhalable plutonium isotopes that could potentially be released from entrainment in the

leakage liquid. LANL uses air sniffer probes connected to radiation detectors. The sniffers are located at the glovebox operator stations to detect any leaks.

Another topic within this issue is a better way to install replacement windows. The current practice is to secure glovebox operations, perform a housekeeping decontamination of the glovebox interior, loosen the existing window, and then increase the glovebox exhaust to maximum (decrease the pressure in the glovebox as much as possible). The loosened window is then removed while the room air is entering the glovebox so that any contamination is swept back into the box. Control measures outside the glovebox include tacky pads and catch pans to immobilize any contamination that might fall during the task evolution. The window and gasket are handled manually and bagged, and the replacement gasket and window are installed. Leak checking by internal pressurization is not performed, since the glovebox interior is contaminated and the staff cannot risk spreading contamination outside the box if there were a leak (this situation is mentioned in Table 2). As a form of leak check, an observation of how well the glovebox pressure responds to the routine air damper settings is made. For most of the Pu-238 gloveboxes, LANL is using a temporary tent enclosure to control contamination during window replacement.

Penetration feedthroughs that have low leakage

The gloveboxes have many penetrations: for coolant piping, for electrical power, for instrument air, and for sensors that monitor glovebox safety parameters (interior gas pressure, criticality, fire protection, etc.). The penetrations are typically clustered on a panel, so there is only one modest-sized opening made in the glovebox wall instead of numerous small openings. Some penetrations at TA-55 have had leaks that were difficult to control, for example, a cracked ceramic insulator or epoxy insulation used in an electrical penetration.

Contamination control when connector spool rings are removed

In some applications at TA-55, several gloveboxes are set up in a glovebox line, connected together by connector spool rings. The connector spool rings are the circular pipe-like pieces that connect gloveboxes together and allow items to be passed between gloveboxes. Connectors can be 18 inches in diameter, or a square configuration of about 12 by 12 inches or 18 by 18 inches. When the gloveboxes are separated for decommissioning, there have been instances of contamination spread when these gasketed connectors are opened. The existing practice is to use catch pans under the connectors during the opening process. LANL personnel are interested in solving this contamination problem, and they are also interested in determining if there is a connector ring that controls contamination better than existing designs.

Decontamination issues inside gloveboxes

There are two reasons to decontaminate the glovebox interior. One is operational - decontaminating during glovebox lifetime. The other reason is decontaminating for disposal. Operational decontamination protects operators by reducing their radiological

exposure in routine operations, or it might precede in-box maintenance, where workers perform periodic maintenance or modifications to the process equipment housed within the glovebox. Decommissioning decontamination is cleaning the glovebox so that it can qualify for low level waste disposal rather than transuranic waste disposal. In either case, all portions of the box must be decontaminated, including the penetration panels, the glovebox corners, and the areas around ports (gas admission and exhaust, around instrument taps, lighting windows, glove rings, etc.). Some of the penetrations or other items are placed close to walls or corners where clearances can be small. There can also be sharp points (crevices, 90-degree sharp edges without any rounding or filleting, inside corners without any rounding, etc.) in gloveboxes that make them difficult to manually decontaminate with wipes or by other means.

An important and costly issue facing TA-55 at LANL is glovebox decommissioning. While a glovebox can have a lifetime measured in decades if there are no concerns over wall material integrity (such as chemical attack that leads to wall breach), generally the TA-55 gloveboxes have a useful lifetime of only 5 to 10 years. Three factors contribute to the shortness of the useful lifetime.

- Changing programmatic needs. The TA-55 program strives to be flexible to meet the needs of the DOE, such as a call for increases or decreases in facility throughput.
- Changing missions. Mission changes require that processes in gloveboxes must be modified accordingly. An example of a changing mission was the mid-1990s task to manufacture Pu-238 radioisotope fuel for the Cassini space mission.
- Upgrades to the facility. An example of an upgrade is an environment, safety and health (ES&H) upgrade to increase the safety of the process or to improve safety and health for the operations staff. Other upgrades are refurbishment to existing process equipment, new experiment design, or new technology use in processes to make them more efficient.

Decommissioning the gloveboxes is expensive for two reasons. First, manual decontamination of the glovebox interior and removal of process equipment from the box is time consuming (several craft people and operators working for up to a month per glovebox to remove process equipment and clean the loose surface contamination). This process alone is estimated to be more expensive than the cost of a new glovebox (new boxes cost on the order of \$30,000 to \$50,000). If the glovebox cannot be decontaminated to low radiation levels it is classified as transuranic (TRU) waste instead of low level waste (LLW). Second, the fact that lead shielding material is built onto the glovebox wall, even though this shielding is clad with an outer layer of stainless steel, means that the glovebox is a mixed waste, since lead is an EPA hazardous chemical waste. The handling and disposal costs are high for mixed waste. For a TRU mixed waste glovebox, the current disposal cost at TA-55 is on the order of \$400,000, shared between DOE Defense Programs and DOE Environment Management offices. For a low-level mixed waste glovebox, the TA-55 disposal cost currently averages about \$150,000.

Because of the high decommissioning costs, glovebox reuse is being pursued whenever possible at TA-55. However, reuse is not always feasible due to several factors: boxes are difficult to decontaminate (a 'dirty' glovebox makes new equipment installation difficult with respect to contamination control), boxes are customized for their initial application (it is easier to custom build a new glovebox than to retrofit an old box for a new application), and any chemical attack to glovebox interior surfaces would preclude its reuse because of uncertainty over its confinement integrity.

The conventional decontamination process requires significant effort. Plutonium isotopes are relatively insoluble, making them difficult to remove from surfaces with chemical decontamination solutions. Acid washes and mechanical action (wiping with rags, scraping with a wire brush, etc.) are used to loosen the contamination. Other isotopes, such as those of uranium, americium, californium, etc., are more soluble and can be taken up from box surfaces with less effort than plutonium. These cleaning processes are painstaking, physically demanding, and when performed through the glovebox gloves, the surface decontamination is not always uniform. A new process being used at TA-55 is electrolytic decontamination [9]. This method, based on electropolishing, allows one operator to clean a glovebox interior to LLW levels in less than a week. The electrolyte aqueous solution is reused; only on the order of 20 to 200 grams of solid material from the glovebox interior surface are removed in a typical decontamination session. This solid is filtered from the electrolyte solution. Thus far, seven Pu-239 gloveboxes at TA-55 have been decontaminated using this method. Four of these boxes were returned to the facility for reuse, one was reused in place, and two were disposed of as LLW mixed waste. This reuse rate of about 70% is promising, but it may not be possible to routinely reuse such a high number of boxes, because of the customized construction and chemical attack issues. Nonetheless, glovebox disposal as low level-mixed waste is much less expensive than disposal as TRU waste, and as low as reasonably achievable (ALARA) considerations also make decontamination a necessary step.

Decontamination of surfaces

This issue relates to the surface texture or surface finish requested when a glovebox is ordered. Typically, 7 gage (0.1875 inch thick) 316 stainless steel is used for dry gloveboxes at TA-55. Appendix B contains many of the glovebox specifications. For example, the 2B Finish for sheets [10] is currently specified for the gloveboxes at TA-55. The TA-55 position is that the 2B mill finish is a shiny, as-rolled sheet finish that is economically produced (no expensive electropolishing or other treatments). The 2B finish cost is small (< \$100) per sheet, as compared with an electropolished sheet that could cost up to a factor of ten more per sheet. The 2B finish is reasonably easily cleaned of contamination. The more highly polished surface finishes have not proven to be as easily decontaminated at TA-55 as the 2B finish. Another aspect of this issue is that the more shiny (i.e., polished) the surface, the higher the glare to the operator. Investigating why the 2B finish appears to work well for TA-55 is of interest to the staff as a glovebox reuse issue.

Ergonomic enhancements for glovebox operators

Several ergonomic issues are being investigated as part of this PP study. One issue is operator visibility and the limitations that window size imposes on visibility. Another issue is the height of the glovebox and the reach distance obtainable with the gloves. The means used to accommodate worker heights at TA-55 are choosing a glove port height to accommodate taller workers and then using metal boxes for other workers to stand upon. The platforms range from 2, 3, 4 or 6 inches high with a standing surface roughly 1.5 by 2 feet. They have a handle for carrying from location to location. The standing surface is equipped with anti-slip rubber strips, since the platforms are generally used where anti-contamination booties are worn. The gloves that are in use are fixed dimensions and employ left-hand/right-hand paired glove sets rather than ambidextrous gloves. The operators often experience hand fatigue after 20 to 30 minutes of in-box operations, and the LANL staff would like to know what can be done to reduce or mitigate that fatigue. LANL personnel are interested to learn of any improvements or suggestions to be made on the present arrangement, and if there are any standard philosophies for designing gloveboxes for people.

Another ergonomic issue combined with a safety issue is access to the elevated workstations on the gloveboxes, those workstations that require the operator to climb up several feet or higher. The LANL operators were aware of the fact that Occupational Safety and Health Administration regulations (29CFR1926.500, subpart M) require either a guardrail, safety net, or personal fall arrest system for employees exposed to falling 6 feet or more.

During a tour of the materials management (waste bagout) room in the waste management area, INEEL personnel noted that the operators must slide the filled 55-gallon drums out from under the gloveboxes. There is only about 1 inch of clearance between the bottom of the glovebox drum-out port ring and the top of the drum. The operators bend over or crouch down and pull a sheet of polyethylene under the drum to slide the drum out into the aisleway. Once the drum is in the aisleway, a drum handler hand truck can then be used to wheel the drum away. Design improvements could simplify this process.

Two good practices noted at TA-55 were the use of anti-fatigue floor mats on the concrete floor in the aqueous chloride processing room and, more importantly, the involvement of the operators in designing new equipment in the gloveboxes. The operators in the chloride room asked for valve handles closer to the gloveports so that the arm reach was shorter; they also requested better clearance around equipment, piping, etc., in the glovebox to allow easier cleaning and housekeeping in corners of the box. These are both good suggestions that, upon implementation, led to more productive operations and better in-box housekeeping.

Lighting in gloveboxes

The present lighting system used for the TA-55 gloveboxes is the familiar, white enamel painted fluorescent bulb fixture (40 watt) fixed to the top of the glovebox exterior

over a ceiling window. The bulbs are typically two feet long. One or more lights are used, depending on the size of the glovebox. The LANL personnel are searching for a standard light that will mate better with the current windows in use, for more effective light into the glovebox at the working level. With the taller boxes that house large amounts of equipment, operators have difficulty with shadows and areas where light fails to penetrate to the floor of the box. Consequently, operators have used a variety of auxiliary lights to illuminate the box through the viewing window. These lights can be high intensity lights, and some success has been achieved with the waterproof, explosion-proof spotlight/floodlight used on miner's caps (specifically, the Ultralight™ cap lamp system from Mine Safety Appliances Company of Pittsburgh, PA [11]), adapted to operate using 120 Volt alternating current instead of battery packs. The bulb does reach high temperatures (up to 400 °F on the bulb surface according to the manufacturer). The lamp provides a white light, which is friendly to the eyes, but operators are nevertheless likely to experience distraction and possibly fatigue from glare because of reflection off the glovebox window.

The LANL staff mentioned that halogen lamps had caused a window to overheat and crack, necessitating replacement. This was also noted in the DOE operating experience review (Section 4.1) for Plexiglas windows.

Another light being introduced at LANL is a fluorescent lamp, the "eco sun lite," from Ericson Fluorescent Light Company in Willoughby, Ohio. This is a waterproof, explosion proof light that uses 0.46 amp at 120 Volts per unit. The units are designed to allow connecting several lights on one circuit, up to 10 amps and 1200 Watts on one circuit (that is, up to 21 units in a chain). Each light unit is about 10 inches wide, about 30 inches long, and six inches high. The units are equipped with rubber pads to rest upon. The primary use for these lights is temporary lighting for maintenance work; hence the waterproof/explosion-proof capability allows use in confined spaces. These lights provide a bright, white light that is important to operators for judging colors and surface textures, a necessary part of some in-glovebox operations at TA-55.

Lighting is also a safety concern and an ergonomics issue. Without proper lighting, operators could conceivably make a mistake during task evolutions within the glovebox. Examples might be selecting an incorrect valve handle, handling the wrong material in the box, or placing a waste container into the wrong waste drum.

If the glovebox interior surface finish is highly polished, then the existing light can become glare to the glovebox operator. The resulting glare fatigue, combined with the important issue of hand fatigue (and perhaps other forms of fatigue as well), limits the operator to work sessions generally no longer than about 30 minutes.

4. LITERATURE REVIEW RESULTS ON THE GLOVEBOX REUSE ISSUES AND CONCERNS

This section is composed of three subsections. The first subsection is a review of recent DOE occurrence reports (ORs) dealing with gloveboxes. Surveying plutonium glovebox faults that have occurred allows correlation of these faults with the issues discussed in Section 3. Included is a list of possible design improvements inferred from the feedback of successes and failures of equipment in the field. The second subsection is a review of literature about design activities, use, and decontamination & decommissioning (D&D) experiences with plutonium gloveboxes. The review includes international activities along with activities across the US DOE complex. The final subsection is an overview discussion of published guidance on glovebox design; where possible the discussion addresses the rationale for requirements and design practices.

4.1 DOE Occurrence Report Review

The DOE's Occurrence Reporting and Processing System (ORPS) data base, which became operational in late 1990, was searched for the set of reports submitted by Plutonium Processing and Handling facilities that contained a reference to a glovebox. This search yielded 1691 reports. Reviewing this entire set of multi-page event reports was not possible given the available time and resources; therefore, nine additional keyword searches of the "glovebox" data set were performed. These searches focused on the preliminary issues being considered by the INEEL staff, as discussed in Table 1. These issues (and the number of reports containing these keywords) are listed below:

<u>Keyword used with "glovebox"</u>	<u>Number of reports found</u>
- Design	27
- Decommissioning	59
- Shielding	26
- Glove systems	65
- Support frames	24
- Gas systems	42
- Cooling water systems	18
- Gaskets	27
- Plastic/Lexan	11

The review of these ORPS reports provided insight concerning many of the problems that have been experienced in recent years at DOE facilities that have gloveboxes for processing plutonium. This information is useful to INEEL engineers in their efforts to enhance the design of a new glovebox system.

Findings

The following information is presented under the general categories of concerns that emerged from the review of the glovebox reports. Note: Where considered appropriate, the

specific ORPS number (e.g., report number ALO-LA-LANL-facility-1996-0001) that was reviewed is provided in parentheses as a reference.

The overriding concern that surfaced was one involving the contamination of both areas and personnel. Reducing the leakage of contamination from gloveboxes is an important waste minimization issue. The internal uptake of contamination by workers was the highest level concern, but in terms of facility resource dollars, the clean-up of contamination resulting from glovebox use is probably the most costly. The possible facility-specific exception to this is another concern of working with plutonium: that is, the migration and undetected deposition of fissile material. Rocky Flats problems involving plutonium concentrations migrating into their air ducts are well documented (for example, see References [12,13]) and, while not discussed here, should be considered in the design of any new glovebox system. A third concern noted in a few ORPS reports involved personnel safety (beyond the internal uptake issue). The discussion of individual concerns follows.

Contamination

Contamination can escape from gloveboxes in a number of ways (e.g., via interface piping and ducts, through defective/damaged gloves or gaskets, and by way of breaches in the glovebox itself). It is important to remember, however, that plutonium gloveboxes are designed to be at a negative pressure compared to the room in which they reside, or they contain an inert atmosphere; thus, many of the contamination events result from problems involving regulation of the glovebox's slight vacuum or its inert atmosphere.

Air flow reversals/overpressure concerns

Reverse airflow and over-pressure problems caused most of the contamination events. A number of conditions/events can cause a glovebox to develop a neutral or even positive pressure. The following are some of the most common causes that were found in the ORPS reports:

- Rubber gloves can be "sucked" into the exhaust grating, thus restricting the glovebox exhaust flow.
- Dirty/dust-laden fiberglass exhaust pre-filters can restrict glovebox exhaust flows, resulting in overpressurization.
- Problems regulating purge gas (e.g., argon) can lead to overpressurization.
- High-pressure air (60 psi) and other pressurized gases used inside gloveboxes can cause over pressurization events.
- An inlet air filter can get sucked into a glovebox past a defective/misaligned fastener, resulting in a glovebox pressure imbalance.
- The lack of design basis documents to support glovebox exhaust ventilation system setpoints led to flow imbalance problems.

- Losses of facility instrument air can affect ventilation damper position and result in glovebox overpressure events.
- Losses of plant cooling water can affect glovebox exhaust fan operability.
- Photohelic pressure controller failed, causing a helium-add valve to open and break one of the glovebox's three laminated safety plate windows. The pressure relief bubbler was also found to contain extra fine steel wool packed tighter than normal (report CH-AA-ANLE-ANLEER-1991-1002).
- Halon fire suppression gas was inadvertently released into a glovebox when a worker "jarred" a thermal detector.
- The simultaneous insertion of two sets of gloves into one glovebox displaced ~32 liters of atmosphere, causing a positive pressure condition.
- Ventilation system fluctuations (caused by emergency diesel generator testing) caused the oil filled pass-through for the balance seal on a glovebox to be empty, which affected the oxygen content of the glovebox (report RFO--EGGR-PUFAB-1995-0097).
- The "blanking-off" of unused gloveboxes at Rocky Flats caused low room airflow (due to reduced exhaust flow), which affected the pressure in the remaining operable gloveboxes in the room.
- Inadequate consideration of the mixing of cold outside air with heated indoor air can result in inadequate airflow to gloveboxes.

Contamination pathways

Airborne pathways include defective gloves, gaskets, bag-out bags, and gas piping. Liquid pathways also involve gaskets, as well as faulty criticality drain systems and poorly designed interfacing systems. Mechanical and chemical reaction problems involving the actual glovebox structure and its windows can result in either airborne or liquid contamination releases.

Gloves

Breached glovebox gloves account for most of the personnel and area contamination. For some perspective to the issue of glove failures, the authors reviewed the latest nine ORPS roll-up reports (each containing one quarter-year of glovebox glove failure data) submitted by the TA-55 facility at LANL. During this period there were approximately 124 reported glove failures (about 14 per quarter). A distribution of the reported glove failure mechanisms is presented below:

• Pinholes/Holes	46
• Tears	24
• Unknown	24
• Cuts	21
• Wear/Age	7
• Burns	2

Though not enough information was provided to determine precisely what activity caused each of these failures, some facts were stated (and others appeared intuitive).

Nine of the glove failures were the result of personnel using the wrong tool or using a tool inappropriately. Another large group of failures was the result of working with sharp non-hand tool items; items such as broken glass, can lids, lock wire, and machine cutting tools. Size reduction and D&D activities are particularly hard on glovebox gloves. Some of the other stated and derived reasons for glovebox glove failures in ORPS reports are listed below:

- Pinholes can develop at stress points such as at the elbow or at any location where a glove may be repeatedly stretched thin (e.g., at the fingertips or around the glove-retaining ring). (Note: Stretching can result from not having long enough gloves to reach work areas.)
- Holes can develop when a glove is subjected to being pinched, usually between items being moved. Armpit area pinching against the retaining ring is known to cause cuts.
- Pre-use inspections have caused tears.
- Long thumbnails have been reported to cause cuts in gloves.
- Aging, which can result from chemical or radiological exposure, was reported much less frequently than was mechanical failure.
- Non-periodic glove replacement schedules almost always results in failures (some facilities have basically been using gloves until they fail).
- Facilities that replace glovebox gloves periodically (e.g., every 6 months) experience few in-service failures.

Note: Bag-out bags experience many of the same kinds of mechanical failures that affect glovebox gloves.

Gasket leaks

Leakage through gaskets used to seal glovebox windows, one glovebox to an adjoining glovebox, and glovebox doors, ports and other penetrations is another source of contamination release. Some of the specific ORPS information involving gasket-related events is provided below:

- A gasket material (unnamed) used at TA-55 experienced Pu-238 enhanced radiolytic decomposition. Chemical reactions were also cited as problems for gaskets. See Reference [7].

- A vacuum grease (brand not stated) used to aid in glovebox window installation can capture contamination and will leak out during window reinstallation or over-pressurization events. High temperatures inside the glovebox will tend to liquefy the grease, thus exacerbating the problem (ALO-LA-LANL-TA55-1996-0040; plus 10 similar occurrences).
- Old hardened neoprene gaskets can break during replacement activities, releasing alpha contamination.
- Windows/gaskets at TA-55 had been in place for about 15 years when they required change-out.
- A sealant (brand not stated), which was applied to a new neoprene glovebox gasket for the purpose of sealing the gasket from old, in-place contamination, failed. The sealant flaked off and fell on the floor, contaminating it. An oil-based epoxy was used in place of the sealant (RFO--EGGR-ANALYTOPS-1992-0044).
- Gasket thickness must be considered when the gasket is used to seal frequently opened doors. Too thick a gasket can result in a door that is hard to shut and puts too much pressure on the door's latch.

Other Contamination Pathways

Other documented and potential contamination pathways include:

- Loose fittings used to connect glovebox O₂ analyzer piping.
- Cracks in stainless steel exhaust ventilation ductwork caused by corrosive (acid) atmospheres.
- Loose (electrical) service panel glovebox penetration.
- Leaky criticality drains.
- Inadequately sized glovebox drain system caused leaking chill-water to back up and leak out through an inlet air filter.
- Paints (epoxy-based) used in gloveboxes and on area floors can become contaminated.
- Radiation shielding made of Benelex can absorb contamination.
- Acid that penetrated the stainless steel lining and the structural floor of a glovebox.
- Glovebox Plexiglas windows are susceptible to melting and cracking if high intensity (e.g., quartz) lighting is placed too close to them. A portable light fell over onto the most severely damaged window. Inspection revealed 11 other gloveboxes in the same building that showed evidence of possible heat damage (RFO--KHLL-771OPS-1995-0043).
- D&D on process systems that penetrated gloveboxes (e.g., the inside of piping, conduits, and ducts were contaminated).
- D&D on old gloveboxes that have had years of contamination buildup and subsequent remediation (i.e., painting over fixed contamination).

Criticality and Safety Concerns

Although area and personnel contamination events accounted for the majority of the ORPS reports that were reviewed, there were a few reports that documented nuclear criticality and personnel safety concerns.

The criticality concern that was cited most often was that of water collecting in a glovebox. In one event, the glovebox drain was not sized large enough to drain the amount of water capable of being supplied to the glovebox by the chilled water system. In another, someone placed tape over the openings in a glass door to reduce a contamination pathway without realizing that these openings served as "criticality drains" for the glovebox.

Other nuclear criticality and safety concerns noted were:

- The draining of approximately 53 gallons of a solution into a hood bay and out the criticality drain without anyone being aware of the situation (alarms sounded but the event occurred on the week-end and there was no automatic shutoff).
- The use of quantities of "Kim Wipes" was questioned when it was determined that a stack of wipes 11" x 13" x 6" could absorb (concentrate) approximately 6 liters of fissile solution. Similar concerns involve the use of "floor-dry" and "oil-dry" absorbents.
- The use of radiation measuring instrumentation inside of gloveboxes whose material structure was not well documented resulted in inaccurate survey results. Those taking the radiation readings failed to realize that a layer of firebricks was attenuating the radiation emanating from the isotope that they were trying to locate/measure.
- The continued use of strong water-based decontamination solutions at some facilities has degraded the grout used to anchor the glovebox support legs (seismic safety concern).

Personnel safety, other than the "uptake" issue, did not emerge as a significant glovebox concern. The few personnel safety concerns that were noted are listed below:

- Unacceptable glovebox temperatures and pressures could result from the combustion of the total amount of plutonium hydride that could potentially be formed by freeing all the hydrogen in a nominal size plastic bag. plutonium hydride is known to form inside drums containing plutonium and plastic bags.
- A glovebox overheat panel (fire detection) was found incapable of transmitting a second (possibly true) alarm if one alarm (possibly false) was already "in."
- While grinding excess epoxy-based paint from glovebox walls, personnel ground into the box's lead radiation shielding (thus creating Pb dust).
- The use of electricity inside gloveboxes to perform certain tasks could result in shocks, especially if the glovebox gloves are deteriorated (i.e., have pinholes).

Lessons-Learned from the ORPS Review

The remainder of this subsection lists observations pertinent to the design, construction, and maintenance of the next generation glovebox system. These observations either came directly from proposed or actual corrective actions stated in, or were inferred from, the applicable ORPS report. No attempt was made to categorize each observation under one of the previously discussed areas of concern (such as air flow reversals/over-pressure). Even so, the statement of each of these observations is explicit enough that the reader should be able to comprehend its significance.

- A better method of attaching gloves to gloveboxes is needed, one that does not use the current style retaining rings.
- Glove lengths must be better matched to glovebox dimensions, in order to reduce the incidence of glove stretching.
- A portable device for testing glove integrity should be developed for use before placing a person's hand into a glovebox glove.
- If such a device cannot be developed, a continuous air monitor type instrument should be used to test the internals of each glovebox glove before use. (Note: Good pre-testing and periodic glove replacement appears to be a better strategy than using a glove until it fails. The latter strategy will always increase the frequency of possible personnel uptake.)
- Gloves should be secured such that they cannot be easily drawn or sucked into the glovebox, as their sudden intrusion can cause an increase in glovebox pressure.
- Leather or Kevlar gloves should be used as a protective covering over the glovebox gloves during size-reduction or D&D activities.
- Some special flexible cut-resistant/puncture-resistant glove material should be considered for work with sharp items and/or tools.
- Glovebox windows and gaskets should be designed for the life of the glovebox (or for easy replacement that does not result in contaminated gaskets).
- The geometry of glovebox windows and gloves should enable the user to see and reach all equipment in the glovebox.
- Glovebox input/output air and liquid balances must be performed to ensure that vents, filters, ductwork, and drains are properly sized.
- Primary to secondary heat exchangers should be considered rather than installing coolant piping directly into gloveboxes.

- A pressure relief system should be installed on any glovebox capable of experiencing a sharp pressure increase.
- Glovebox gas-add systems should be designed fail-safe in order to limit over-pressure excursions.
- The glovebox needs to be designed with an interface that will permit taking the glovebox completely out of service without affecting the total room airflow.
- Glovebox fire detection equipment must meet all current National Fire Protection Association (NFPA) codes.
- Gauges should be selected that can be calibrated without having to open them up (contamination concern).
- All latches (doors, etc.) should be lever-type, not friction-type.
- Equipment generated vibration (e.g., from fans) should be considered when selecting glovebox instrumentation.
- Stainless steels should be selected based on their resistance to materials/chemicals that will be processed in the glovebox (Type 304 SS develops cracks when exposed to corrosive (acid) effluents).
- An alternative would be to install scrubbers and condensers to remove corrosives from the glovebox atmosphere.
- All structural materials used to construct gloveboxes or their interfacing equipment (e.g., a furnace) should have documented radiation attenuation numbers.
- Welded fittings, rather than bolted flanges and gaskets, should be considered when contaminated leakage is a possibility.
- Periodic preventive maintenance or replacement should be considered for all glovebox interfacing equipment that is used to maintain pressure or control airflow.
- If Plexiglas windows are used, heat sources must be positioned such that they will not cause the windows (or any other materials) to overheat.
- Paints and sealants should be selected based on their low contamination absorption properties. Materials currently in use tend to absorb contamination and then flake off, spreading contamination to areas and personnel.

- Because of the potential for gas fire/explosion, the use of oxyacetylene welding cylinders is prohibited at some glovebox facilities. Tungsten inert gas welding equipment must be used instead. A question for designers is "If a glovebox was constructed using oxyacetylene welds, will tungsten inert gas welding produce 'compatible' repair welds?"

Some good and bad products named in the reviewed reports include:

Good products

- "Frham Tex II" protective suits were determined to be better than Tyvek suits.
- Neoprene gaskets are compatible with acidic environments (e.g., nitric acid).

Bad products or practices

- Criticality drains without a liquid-seal (a contamination release concern).
- "Benelex" radiation shielding (this shielding readily absorbs liquid contaminants).
- "America District Telegraph" glovebox over-heat monitors (they are prone to false alarms).
- Magnehelic differential pressure gauges (they cannot be calibrated without subjecting personnel to excessive contamination concerns).
- "Hoffman" electrical connection boxes (they are too small in terms of working space).
- "Kathene" (lithium chloride brine) coolant (it is highly corrosive to concrete/grout).
- Strong decontamination solutions (they can also cause grout to degrade).

4.2 Review of Recent Literature on Gloveboxes

Computerized and manual literature searches were conducted to find reports and articles that discussed glovebox design, operation, and decommissioning, since these topics are most germane to the list of eight issues. Many of the articles were found to have been submitted to the American Glovebox Society, which indicates that this society is able to form information links across the DOE complex. Such linking is valuable in that it allows researchers to draw on the experiences of other laboratories in the complex, so resources and trial applications, equipment tests, good practices, etc., are shared. This interaction should be maintained and encouraged as much as funding allows, since sharing experiences is a cost-effective means to advance the state-of-the-art.

The literature review included several articles discussing glovebox construction activities. The article by Purson et al. [14] discussed keeping the glovebox design as standard as possible to minimize the price and the delivery time. Nonetheless, an extra wide standard glovebox would not accommodate the components to be confined, and it was necessary to use a window frame extender to enable the glovebox to confine the

equipment. The designers paid attention to the glove reach for access to the entire glovebox volume. The equipment to be confined in the glovebox was too long for a two-standard section glovebox, and three sections were too long to fit in the floor space, so the glovebox was shortened to ten feet in length; this decision did not greatly affect fabrication cost. A 'tophat' extension was also needed, although this is a non-standard item. Hypalon gloves 15 mil (0.38 mm) thick were used to increase operator dexterity. These thinner, unshielded gloves could be used since tritium was the major isotope to be confined in this glovebox.

A design description from the United Kingdom [15] discussed installing a new glovebox facility for PuO_2 , with a lifetime of 20 to 25 years. The shielding of gloveboxes was discussed, since many plutonium isotopes would be handled in the boxes. Lead 10-mm-thick was used for gamma ray shielding, and 110 mm of paraffin wax was used on five faces of the glovebox for neutron shielding. No neutron shielding was used on the front face at the operator's workstation; the loss of 110 mm of reach was very important, and the infrequent time spent at the workstation meant that neutron doses would be low for the operators. The gloveboxes were built as double skinned units with the lead and paraffin being contained within the double skin. Since their experience was that the major risk of incurring internal doses was during maintenance work on piping, filters, and box servicing, a maintenance/service glovebox was designed to be connected with the operations glovebox. A lead lined transfer tunnel, 250 mm in diameter, linked the two gloveboxes. Mockups built from wood were used to determine the details of pipe and cable runs, valve positions, etc.

A waste processing glovebox design was described by Wahlquist [16]. The glovebox was constructed of 0.125-inch-thick stainless steel, with 0.25-inch-thick stiffening plates. The ventilation system can draw 125 feet/min air into the most credible breach opening. Fluorescent light banks, 2 feet by 2 feet and 1 foot by 4 feet, were used for illumination. The glovebox windows were fastened using zippered rubber molding. Ambidextrous gloves, 32 inches long and made of 30 mil (0.76 mm) thick neoprene were used in 24 gloveports. A hoist was provided for material handling, controlled by a hand-held remote control transmitter. During fabrication, there was warpage when stainless steel panels were welded to the carbon steel frame. This was a particular problem for window sealing, and panels needed cutting, welding, then grinding and the addition of unistruts to pull them flat to within 0.0625 inch per linear foot so the windows would seal without leaking or cracking. Interior corner joints were too sharp to decontaminate, so epoxy material was applied to all joints using a one inch radius putty knife. The entire glovebox design and fabrication cost, including the internal equipment, was \$425,000.

Rosenberg et al. [17] discussed their experiences in designing a glovebox to house a gas generation experiment. Due to the customer's compressed time frame for the project, the research and development, design, and fabrication could not be conducted in a serial fashion. The glovebox shell size was selected and the fabricator proceeded with construction while other features were designed. The shell dimensions for the argon atmosphere glovebox were 276.75 inches (703 cm) by 43.3 inches (110 cm) wide, and 112 inches (285 cm) high. A false floor was used in this glovebox. The designers constructed a mockup of the glovebox to test for gloveport locations and height on the box

wall. An optimum gloveport height was selected from the tests on the mockup. The mockup was also used to determine locations of service penetrations (electricity, instruments, etc.) and to test the design of the bag-out system. The operator's working platform was mocked up and an optimum height was determined from testing with the mockup.

Friego [18] published a set of design features in a checklist form for design professionals to use when formulating and reviewing designs. The list is quite thorough, but there is no guidance on how to implement the checklist requirements. Nonetheless, having a list of items that must be integrated during the design process can be useful.

The authors found no articles retrieved that dealt with glovebox operations. Some articles described glovebox failures, such as the DOE/DP-0018 report from 1993 on DP facility occurrences, but these are encompassed in the DOE occurrence report review in Section 4.1.

Several articles discussed recent experiences with glovebox decontamination and decommissioning (D&D). Rose [19] and Baker [20] discussed D&D in the vicinity of non-radiological areas, and how the glovebox design criteria were appropriate for siting and lab room location, but were not always the most conducive to D&D tasks. Sixty-one gloveboxes that had been used over the past 30 years at Argonne National Laboratory were D&Ded. These boxes had equipment removed from them in roughly 1,000 pouch out operations that filled 165 55-gallon drums with transuranic (TRU) waste. One operator was exposed to contamination by a glove failure during the size reductions of equipment to allow it to be pouched out. The gloveboxes were assayed to determine the extent of contamination and the residual contamination after the gloveboxes were cleaned. During these surveys, unexpected isotopes (Cm^{243} and Cs^{137}) were found in 11 of the boxes [19]. The gloveboxes contained many corners and crevasses that trapped contamination. A water-based fixative (Aqualac®) was used on all gloveboxes to secure contamination that could not be removed by wiping. A structure was built to contain the size reduction operation. The 61 gloveboxes were disassembled and cut to reduce them in size, and then they were packaged. That process took about 4 months.

Boing et al. [21] discussed the waste minimization techniques used in decommissioning the 61 gloveboxes at Argonne National Laboratory. Generally, D&D is conducted in a manner that makes best use of the time allocated to the work. There is a trade-off between time and waste sent for disposal, and in the future, more focus will be given to performing D&D such that more material will be released for recycling and reuse rather than packaging it for disposal. Argonne personnel had success with free-releasing lead shielding used at the Experimental Boiling Water Reactor, and they used it in a new shielding application at an accelerator. They used contaminated paper, plastic, and cloth as void filler in boxes; this substitution saved the cost of clean fill and reduced the number of waste boxes needed. Three of the gloveboxes in the set of 61 boxes were reused at Argonne in the D&D department, saving about \$15,000 in new purchase costs. Use of the Pajarito Scientific Corporation waste assay system resulted in 10% of the drums from the glovebox D&D activity being reclassified as low specific activity waste rather than TRU.

This reduced the amount of waste that had to be stored on-site until a TRU waste repository opens.

The Sequoyah Fuels Corporation published a report on design issues to facilitate D&D work [22]. In that report, they discussed the ongoing D&D activity on the Cimarron Plutonium Facility that was built in 1969, near Crescent, Oklahoma. The gloveboxes used at Cimarron were fabricated specifically to confine plutonium in the fuel pellet fabrication processes, using 0.1875 thick stainless steel glovebox shells and bag-in/bag-out techniques. The gloveboxes were many sizes and shapes, designed to fit specific locations of the plant, some boxes required three working levels. The facility design of minimum floor space to minimize clean-up requirements between fuel enrichment cycles made D&D shielding, equipment isolation for contamination control during dismantlement, and radiological assay procedures very difficult. Radiation shine was a continual problem for D&D workers. Glovebox clearing was hampered by the close quarters. The custom design of the gloveboxes resulted in D&D problems during sectioning and cutting since the D&D equipment could not be standardized. The suggestions for future glovebox construction were:

- Sufficient floor space around and inside the gloveboxes for ease of access in D&D and to permit isolation and shielding of gloveboxes for accurate non-destructive assay.
- Design to standardize the gloveboxes when possible to simplify glovebox cutting for disposal.
- Inside and outside surfaces of gloveboxes should have a high gloss finish for ease of decontamination. Inside corners should have generous radii. Gloveboxes should be located away from walls to allow access to all sides for cleaning and decontamination. Transfer tunnels between boxes minimize the potential for spreading contamination and reduce the bag waste from bag-in/bag-out transfers.

Smith and Hootman [23] described the D&D activity at the Savannah River Plant. A 10,000 square foot Pu-238 processing facility had been undergoing an intermittent D&D activity for 9 years, and half the floor space has been D&Ded. The authors noted that the design of the plutonium handling facility had been for efficiency of operation and not for ease of D&D. Even if a facility is designed for ease of D&D, modifications made during operations may present formidable D&D challenges. One notable practice was that an extensive set of photographs was taken for reference before D&D operations began, and the photos were used for pre-entry briefings during dismantlement operations; this made the operations more efficient. About 213,000 cubic feet of solid waste was generated, about half was TRU and half was LLW; less than 500 cubic feet was mixed waste, primarily from lead shielding. Glovebox segments up to 2 feet by 3 feet by 4 feet were packaged intact for long term on-site storage. Thus far, the task has cost \$12.5 M.

LaFrate et al. [24] discussed some of the D&D operations at LANL's TA-21. This document gives a fairly detailed description of glovebox decontamination, contamination

fixing, disassembly, and size reduction. No mention is made of how lead shielding was handled; only TRU and low level waste containers are mentioned. The gloveboxes proved easier to D&D than did the exhaust ductwork. The one Pu-238 glovebox required about 30% more handling time than a similar Pu-239 glovebox, since Pu-238 contamination control was problematic. The Pu-238 permeated the outer Tyvek layer of anti-contamination clothing. Plastic glovebags were used during the duct brush-down decontamination task; the bags were adapted from asbestos removal bags. When the task was completed, the team concluded that it is possible to D&D TRU ducts and gloveboxes safely and economically.

The literature review included a few references to European work in the area of plutonium glovebox decontamination. Caillol [25] discussed work at Cadarache. A mixed oxide fuel fabrication complex was D&Ded to allow for modernization. A 400-square-meter floor area was cleaned and made available for new equipment. Over 100 cubic meters of gloveboxes were dismantled, some metal and some plastic. In France, waste drums with more than 5 g of plutonium must undergo plutonium recovery treatment, and drums with less than 200 MBq (about 10 mg of plutonium) can be sent to shallow land burial. The lightly contaminated gloveboxes were removed from the building and size reduced in a manually operated size reduction cell. Heavily contaminated gloveboxes were taken to an industrial scale facility for low temperature impact crushing (using a cryogenic tunnel, a hammer mill, and washing equipment). Fully equipped gloveboxes up to 2 cubic meters were size reduced by a factor of 6 and decontaminated by 90%. A glovebox line of five boxes totaling 50 cubic meters was dealt with as a single unit. A size reduction tent was erected, made of polyurethane panels and Plexiglas viewing windows. The tent had air locks for personnel access and waste bagout. Workmen used supplied air suits. Size reduction took 400 person-days, working in two- and three-man teams. Their total group gamma exposure was 48 mSv. The team concluded that remotely operated size reduction methods are needed to keep dose rates low.

Smith [26] reported on recent work in the United Kingdom, consisting of D&D of seventy fuel fabrication mixed oxide fuel plutonium gloveboxes at the Winfrith Technology Center. A modular containment system (MCS) was developed as a confinement enclosure around the gloveboxes. The MCS used glass reinforced plastic panels, coated with a strippable coating and bolted together for a self-supporting structure. After a glovebox was prepared for D&D, the MCS was built around the glovebox, and the windows were removed. Then the windows and the box shells were size reduced using saws or nibblers. The sections were passed to waste drums via bagout ports. The gloveboxes that housed highly contaminated machine tools were found to contain many tens of grams of plutonium. The MCS was extremely beneficial for confinement, and it generated a minimum quantity of waste. Using power and hand tools facilitated rapid and economical glovebox size reduction.

This review has shown that many gloveboxes must be custom designed to accommodate the equipment to be housed, designers are conscious of some ergonomic principles (depth of reach, gloveport height, and other measurements), and that wooden mockups have been useful endeavors for several designs.

The D&D experience review has shown that designs have not always considered decommissioning concerns (e.g., glovebox exterior access for segregation to assay), and that some gloveboxes are sectioned to fit into disposal containers. With short lifetimes, consideration of D&D aspects in design is important to reduce disposal costs and minimize waste mass/volume during D&D.

4.3 Review of Applicable Design Regulations and Guidance

There are several regulatory documents for design of gloveboxes. For several years, the regulation used to direct glovebox design was DOE Order 6430.1A, "General Design Criteria." This Order has been canceled by DOE Order O 430.1, "Life Cycle Asset Management," change 1, October 26, 1995. DOE Order O 430.1 directed that DOE 6430.1A is still in effect for facilities under the purview of the Defense Nuclear Facilities Safety Board until DOE O 420 ("Facility Safety") is approved for defense nuclear facilities. Therefore, DOE Order 6430.1A still influences glovebox design for facilities like TA-55. 6430.1A has sections on enclosures (Division 11), human engineering (Section 1300-12), plutonium processing and handling facilities (Section 1304), and ventilation (Section 1500). The general design criteria do give fairly detailed qualitative design criteria, but not much guidance on how to meet the criteria, and only a few quantitative design values. Most of these are left to the facility designer and the authority having jurisdiction over the facility. Since the glovebox is primary confinement, it is called upon to protect the workers (and the environment) by confining particulate plutonium. Division 11 calls for standardized design in these areas: windows, gloveports, ease of interior glovebox cleaning, illumination, service line connections, fire barriers, filter installations, sample removal ports, pressure readouts, and glovebox interconnections. Division 11 does not define what the standard should be in those areas.

Glovebox fire safety guidance is found in DOE Standard 1066-97, "Fire Protection Design Criteria," 1997. This standard discusses gloveboxes from internal fire and exposure fire considerations. Fire issues are important to plutonium gloveboxes because of the large, costly, hazardous fires that have occurred with plutonium handling (for example, see Reference [27]). Fire spread considerations and criticality considerations, as well as issues involving separation of fire suppression agents from process metals, are discussed.

There is a guide issued by the DOE, "Nonreactor Nuclear Facilities: Standards and Criteria Guide," DOE/TIC-11603-Rev. 1, 1986, that provides some additional qualitative guidance for plutonium handling, but it typically refers to DOE Order 6430.1A.

No other DOE guidance documents on glovebox design or operation were found during the literature search.

There is some Nuclear Regulatory Commission (NRC) guidance on gloveboxes published in the Federal Register (Volume 57, Number 154, August 10, 1992, pages 35607-35613, "Guidance on Fire Protection for Fuel Cycle Facilities"). Fuel cycle gloveboxes should be of noncombustible construction, and if a number of gloveboxes are operated in series, fire dampers should be provided at intervals to impede propagation of

fire. Quantities of combustible materials and sources of ignition should be maintained at an absolute minimum, and inert atmospheres should be used when there could be flammable or explosive gases in the glovebox. Extinguishing agents compatible with the materials handled should be provided, with consideration of nuclear criticality concerns. Filters for the exhaust air from a glovebox should be of noncombustible construction.

There is some other nuclear industry guidance for glovebox design. The International Atomic Energy Agency (IAEA) has a publication, "Safe Handling of Plutonium," IAEA Safety Series No. 39, 1974, that discusses glovebox design. There is good practice guidance in this document, including marking the gloves with their installation date, some quantitative guidance on glovebox pressure relative to the room air pressure, and some rules of thumb for atmosphere changes per hour. This guide states that the minimum number of gloveports should be two, and it is preferable to have at least three, so an assistant can help the operator if needed. There is guidance that the glovebox internal pressure should be in the range of 20 to 30 mm (0.79 to 1.18 inch) of water below room pressure, since the sense of feel when working in the gloves is adversely affected by negative pressure in excess of 30 mm of water. The most comfortable position for the operator's arms when they enter the glovebox is at a slight downward angle, and the lower end of the glove opening should be about 3.9 inches (10 cm) above the floor of the glovebox for maximum operator comfort. Normally used dimensions are: port openings on the order of 5.9 to 9.8 inches (15 to 25 cm) in diameter, and about 15.7 to 17.7 inches (40 to 45 cm) apart (gloveport center to gloveport center). The suggested convenient depth of reach into the box is 25.5 inches (65 cm). An important note is that rapid movements of gloves in boxes can easily cause overpressure in the glovebox (this was also mentioned in Section 4.1 of this report).

Another IAEA publication that briefly discusses gloveboxes is "Manual on Safety Aspects of the Design and Equipment of Hot Laboratories," IAEA Safety Series No. 30, 1981. Much of the discussion was already captured by the previous IAEA report, but this publication does address hypalon gloves as being resistant to solvents and ultra-violet light, and being more leak-tight than natural latex rubber.

The American Society for Testing and Materials (ASTM) has a document, "Standard Guide for Design Criteria for Plutonium Gloveboxes," ASTM C 852-93, that provides several quantitative values for designers. The standard is brief (4 pages), but it is nonetheless useful. It briefly covers confinement, construction, materials, windows and ports, gloves, bagout, in-box lighting, ventilation, fire protection, criticality prevention, services, radiation shielding, wastes, and monitoring and alarm systems, and it briefly mentions decommissioning. Aside from lighting, no ergonomic considerations are discussed.

The American Nuclear Society has published a guidance document for hot cells, "Design Guides for Radioactive Material Handling Facilities & Equipment," 1988. There is some applicability to gloveboxes, in the areas of illumination lighting, windows, some maintenance issues, support systems, fire protection, wall liners, and other topics. There

is both qualitative and quantitative guidance in this document, but no discussion of ergonomics.

A good practice manual, titled "Health Physics Manual of Good Practices for Plutonium Facilities," PNL-6534, May 1988, discusses gloveboxes. Section 3 of this manual suggests using glovebox confinement for handling quantities over 100 mg of plutonium isotopes. Personnel in routinely occupied areas should not receive more than 0.5 mrem/hour dose. The manual also states that fire dampers shall be provided between gloveboxes to limit the spread of fire. The process design should minimize required hands-on operation in glove boxes, and sufficient work space shall be in the design to allow easy personnel access to all normal work areas as well as collection, packing, storage, and disposal of waste generated by operation of the glove box. Box-to-box transfer systems are suggested. Operator visibility, accessibility to controls, and ease of cleanup and waste removal are directed to be incorporated into the glovebox design. Ergonomics shall be considered in designing the height of ports and access to inner surfaces and equipment. Penetrations should be minimized, and overpressure protection shall be provided. Construction materials must be non-combustible and resistant to chemical attack. The use of organic (plastic) materials is not recommended for use in plutonium gloveboxes because of alpha particle deterioration.

The American Glovebox Society (AGS) has a guidance document titled "Guidelines for Gloveboxes," AGS-G001-1998. This document is a compilation of good practices and requirements for glovebox designers. There is both qualitative and quantitative guidance in this publication, which is a consensus of best practice information, compiled from society members. The document contains information on all phases of glovebox use (design suggestions, operation, maintenance, and decommissioning), and engineering drawings of some glovebox equipment. Some ergonomic considerations are discussed in this publication. It is the most comprehensive guidance found during the literature search.

The National Fire Protection Association (NFPA) has a consensus standard on fire protection of laboratory equipment that includes gloveboxes. This standard is entitled "Standard for Facilities Handling Radioactive Materials," NFPA 801, 1995 edition. This standard specifies that any shielding materials, permanent or temporary, must be noncombustible. All gloveboxes handling pyrophoric materials will use a means of fire detection, and the number of gloves shall be limited to the minimum number necessary to perform operations. Gloves not in use shall be tied outside the box. In-box combustibles shall be minimized, and fire barriers shall be provided between glove boxes operated in series. Either noncombustible filters will be used, or a fire suppression system will be installed. Daily documented housekeeping inspections shall be performed on each glovebox.

Some qualitative, overview design guidance is found in this text: O. J. Wick, editor, Plutonium Handbook. A Guide to the Technology, 1980. Wick also refers to a report by N. B. Garden, editor, "Report of Gloveboxes and Containment Enclosures," TID-16020, 1962, as an initial effort at standardizing glovebox construction and operation in the US Atomic Energy Commission. The Garden report gives some insights as to why

gloveboxes have developed as they have, for example, circular gloveports rather than oval ports. The Garden work cites that ovals were more expensive than circular cut outs in the glovebox, and that it was difficult to seal circular cross section gloves to oval ports. It is implied that the operators still had tolerable range of motion with circular ports, so oval ports were not pursued any longer and circular ports became the standard configuration.

The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) has a handbook, 1995 ASHRAE Handbook, Heating, Ventilating, and Air-Conditioning Applications, that discusses gloveboxes briefly in Chapter 23, "Nuclear Facilities." It generally refers back to DOE Order 6430.1A. There is little design information in this handbook that is not given elsewhere.

The American Conference of Governmental Industrial Hygienists (ACGIH) has a guidance document entitled Industrial Ventilation, a Manual of Recommended Practice, 22nd edition, 1995, which gives a brief reference to gloveboxes, and gives a sketch of a glovebox.

An impressive volume of information is in the text Glove Boxes and Shielded Cells for Handling Radioactive Materials, Academic Press, 1958. While some information is dated, this conference proceedings volume gives much background to the design rationale and describes foundational design practices. There is a section that describes LANL gloveboxes; while some changes have been made to accommodate new technology and manufacturing processes, much of the information is still worthwhile. For example, lead shielding is now incorporated into the glovebox design, and only a few locations use portable lead radiation shields. Gloves are typically made with hypalon and are lead-lined now, rather than simply made from neoprene. This text can be consulted to determine if any ideas about the gloveboxes have already been tried in the past, and to determine the contrast between past practices and present issues.

This review of design guidance shows that there are conflicting suggestions for glovebox design. For example, the NFPA suggests small viewing windows and the fewest number of gloves possible, since these are the weakest areas of the glovebox confinement wall and there is the ever-present concern of a pyrophoric plutonium fire or dust explosion that will threaten to fail glovebox confinement, which would lead to release of plutonium. Such releases could result in worker exposure and perhaps environmental contamination. The IAEA guidance suggests that more than one operator workstation is useful to have an assistant help the operator if needed, which is a practical suggestion from an operations perspective. The design guidance also shows that there are many practices that are universal, due to the prudent safety practice and positive feedback from existing designs. An example is sealing gloveboxes to sufficient leaktightness that inert gas (argon, etc.) boxes can be operated at subatmospheric pressure without undue concern for accumulating inleakage air.

5. INITIAL ANALYSIS OF ISSUES

This chapter provides an initial analysis and assessment of the eight technical issues listed in Section 3. The issues are discussed in order. Preliminary alternatives to resolve these issues are discussed.

5.1 Lead Shielding Sandwich on the Glovebox Exterior

As part of this study, The authors had the opportunity to observe several phases of construction of a new glovebox for TA-55 at the Diversified Metal Products Company in Idaho Falls, Idaho. The authors observed the fit-up of the glovebox corners, the fit-up of 0.25-inch-thick lead shielding, as well as the preparations for placing the stainless steel skin on the outside of the lead. The authors also viewed gloveport installation and preparations for glovebox leak testing. There are several ideas for easier removal of the lead from the glovebox during D&D. If the stainless steel skin can be cut open, some of the solid shielding sheets can be lifted out since the lead sheets are typically not fixed to the glovebox wall. Other lead sheets that are glued to the glovebox wall would require more effort to remove, perhaps using a solvent to debond the lead sheets, or mechanical means can be used to pry the lead from the wall. Cutting the stainless steel skin from the gloveport area poses a concern, since the lead is sized exactly around the opening. It may be possible to suggest a fabrication technique that will allow the lead to be removed from under the gloveport ring mounts. Another potential alternative, although more costly and elaborate, would be to study a concept of sectioning the glovebox in a tent enclosure using some means of cryogenic or water jet cutting to reduce lead aerosol generation. A major concern is not contaminating the lead with any remaining contamination from the glovebox interior surfaces. With the box sectioned, the lead that cannot be removed manually could be separated by melting with the use of an inert atmosphere furnace. This is possible since lead melts at around 330°C and stainless steel melts at about 1400°C. The lead could be cooled in ingot castings and upon examination it may be possible to free release the lead as a non-contaminated solid, or, if it is contaminated, at least there has been volume reduction of the mixed waste (the large glovebox can be disposed of as LLW). This idea and others to implement lead shielding removal will be studied.

5.2 Window Gasket Seal Leakage and Lifetime

A study of gasket materials [28] compared neoprene, urethane, viton, and hypalon elastomers in a plutonium (Pu-238 and Pu-239) glovebox environment for three years. After the exposure period, the samples were compared to non-exposed control samples that had been held for the same time duration. The hypalon was unchanged for the three years, it was clearly the best performer of the tested elastomers. The study concluded that hypalon could provide better serviceability and operator safety when used as a glovebox gasket over the present material of choice, which is neoprene.

It would be prudent to explore why hypalon is not being used as a gasket material. Perhaps there are compatibility issues, manufacturing reasons or cost issues in developing

a hypalon gasket that preclude its use on plutonium gloveboxes. This issue can be researched and a vendor study performed.

A related issue is the installation of replacement windows on gloveboxes. The processes used at other laboratories will be examined to compare with the LANL window change procedure (511-GEN, "Procedure: Changing Glovebox Windows"). The comparison will allow us to determine if there are any enhancements that can be adopted at TA-55 or if it is the best practice possible for the given equipment and circumstances.

5.3 Penetration Feedthroughs That Have Low Leakage

This issue has apparently been solved for new glovebox orders by requiring the glovebox vendor to be able to certify the hermetic seal on the service penetrations as part of the glovebox acceptance process [29].

There are still existing gloveboxes at the facility, and some of these have concerns about small leakage through the penetrations. That issue requires further study before any suggestions can be made.

5.4 Contamination Control When Connector Spool Flanges are Removed

One way to reduce the contamination potential from glovebox connector spool flanges when they are opened would be to use a gasket that offers better confinement of the contamination. The authors will review the LANL glovebox standard drawings for details about the present design. Another task would be determining if the hypalon gaskets discussed above are made in sizes compatible with spool piece gasket needs, and if hypalon could be used in place of neoprene.

There is technology available from another activity that might be useful to control contamination when removing the connectors. Glovebags designed for asbestos removal activities [30,31] could be explored for possible use in these connector piece operations. The plastic enclosure would be a more robust level of confinement than the catch pans below the connector spool piece. Working through these bags would add time to the task, and some contamination would probably remain on the glovebox outer walls, so catch pans and surface wiping would still be required, but the bags should stop any appreciable airborne releases. Somewhat larger spaces between the gloveboxes would facilitate moving the gloveboxes and using these bags.

5.5 Decontamination Issues Inside Gloveboxes

The issue of removing sharp points cannot be easily resolved for existing gloveboxes, although it appears from Section 4.2 that this is a pervasive issue during D&D. The close quarters (generated by penetrations close to corners, etc.) for decontamination equipment to reach all parts of the glovebox is likewise not easily solved for existing gloveboxes. A possible future design requirement is to consider that some type of decontamination appliance that requires a specific number of square inches clearance

must be accommodated. The new LANL process using electrolytic decontamination has been very successful thus far, so design with adequate clearance for those cleaning fixtures taken into account might be another possible future requirement.

5.6 Decontamination of Surfaces

The issue of what surface finish can be decontaminated most effectively, and why LANL has had success with the 2B mill finish, can be researched. Comparisons between the DOE plutonium handling sites can be done to determine if there is a surface finish that is better than the 2B finish. For example, Argonne National Laboratory-West has had success with the number 4 surface finish. A study performed in the United Kingdom showed that the 2B mill finish was not as easy to decontaminate as the electropolished finishes [32] when using ultrasonic cleaning. However, some work at the Savannah River Site suggested that the 2B finish was less difficult to water blast decontaminate than other finishes [33]. The Savannah River personnel believed that this performance was due to the rougher surfaces not offering the same level of particle contact. Obviously, the issue needs further research.

Cleaning techniques that do not rely on mechanical impact (an example of an impact technique is sandblasting) may be the solution rather than simply specifying a surface finish. Matching a surface with an optimum decontamination method could give the best results.

5.7 Ergonomic Enhancements for Glovebox Operators

Three key principles of ergonomics are: (1) fit the task and the workplace to the individual rather than forcing the individual to fit into the workplace, (2) design the workplace for workers with a range of body sizes, not just one average size, and (3) design the workplace for individuals at the extremes of the body-size range [34]. When multiple workers will use a workstation (i.e., a work area, not a computer), such as multiple operators needing to use the same glovebox gloveport workstation, then the latter two principles must be used. The last principle means to extend the range of body-sizes as much as possible, even the 5th percentile size up to the 95th percentile size person (this principle has been specified in DOE Order 6430.1A, Section 1300-12.4.2 "Human Dimension Considerations"). The designer must determine the population that will be using the equipment and meet that population's needs. By the nature of their confinement function, gloveboxes do not lend themselves to ergonomic solutions. Nonetheless, any improvements that might make the operator more effective and more comfortable when using the gloveboxes would be worthwhile. Suggested improvements would have to be evaluated individually and perhaps used on a trial basis to determine if the TA-55 operators will benefit from them. A survey of ergonomic bases for glovebox dimensions will be performed.

The issue of working at heights can be partially addressed. INEEL can survey available ladder and portable stair equipment to determine if there are any alternatives for

LANL operators to use that will enhance ergonomics and operability, keeping in mind that there is limited storage space in the basement of the PF-4 building.

The drum sliding from under drum-out gloveboxes is an issue that can be addressed. Briefly, if a coefficient of friction for a polyethylene sheet on a seal coated, smooth concrete floor is assumed to be a low value of perhaps 0.2, and that a drum can weigh from 200 to 500 pounds, then the maximum force that must be applied to start the drum moving is 100 pounds force. Using Table XXIV from MIL STD 1472E [35] shows that the exertable pull force for a male over short time periods (with low traction, an appropriate assumption when the operators are wearing anti-c's and booties) is 25 pounds force. This value can be summed for up to three males working together, but for the fourth and any additional personnel the standard suggests only adding 75% of their pull force. This would mean that for the heaviest drums, five operators are needed to move the drum out to the aisleway. With less than five operators, this means that the drum-moving operators could be overexerting themselves at each drum removal operation (perhaps twice per day). A lower friction approach, perhaps some type of lowboy cart to roll the drum in and out from under the glovebox, would reduce the human effort needed to move the drum to the point where the drum handler hand truck can be used.

INEEL can support LANL by surveying and summarizing the ergonomic rules and guidance that apply to gloveboxes, making some suggestions to enhance operator effectiveness and comfort, examining some of the ergonomic aids in use at TA-55, and suggesting a conceptual design for a simple machine to more easily move the waste drums out from under the drum bag out ports in the existing materials management room.

5.8 Lighting in gloveboxes

This issue falls under the ergonomics category. The LANL staff is attempting to solve the problem of insufficient light at the glovebox floor by using high intensity lights, miner cap lamps, outside the glovebox. For some applications, this is successful, and the "eco sun lite" that has recently been procured for a glovebox-top light may reduce the need to use the cap lamps aimed through the main viewing window. One interesting idea proposed by INEEL is the use of a rope light inside the glovebox, placed around the main viewing window. The initial test of a representative, commercially-available rope light (\$70) at the training facility at TA-55 in June 1998 showed that this light qualitatively gives acceptable brightness to illuminate operations where the operator is working, but give a yellowish color light rather than white light. The yellow light may not be acceptable to the operators, who need to distinguish material color and surface texture for some in-box tasks. The rope light must also be evaluated for its reliability, service life, and safety concerns when admitted into a glovebox. The rope light can be investigated for possible use of different bulbs that produce the desired white light.

Other lights that might be useful at TA-55 (used outside the gloveboxes) can also be investigated, particularly those whose bulb surface temperatures are not as high as halogen bulbs. Incandescent bulb surface temperatures can range from 40 to 200°C, or higher for

higher power bulbs (over 300 Watts). Fluorescent bulbs typically run much cooler than incandescent bulbs, with surface temperatures usually in the 35 to 45°C range.

In-box lights are typically not used since there are concerns regarding bulb disposal as contaminated waste, possible bulb breakage in the box (either during replacement or operations), and possible bulb breakage in a waste drum (leading to sharp glass fragments that could cut plastic bags). Incandescent bulbs are used inside gloveboxes in a few locations.

6. CONCLUSIONS

The authors have completed the first phase of a pollution prevention study to examine waste minimization issues related to the use, decontamination, possible reuse, and disposal of TA-55 gloveboxes. Consistent with the memorandum of agreement [1] that directed this effort, the authors have collaborated with LANL TA-55 personnel, participated in facility tours, and researched existing literature in defining the associated waste streams and identifying relevant issues. The results of this effort so far indicate that waste associated with glovebox use and D&D can indeed be reduced, through (a) cleanup and reuse of some gloveboxes, (b) improved glovebox designs that better facilitate decontamination and waste separation, (c) ergonomic improvements that enhance operator efficiency, and (d) design and materials improvements that enhance contamination control.

Certain design features (gloveport size and shape, etc.) have already been standardized. The authors do not recommend further standardization of glovebox shell design as a means of minimizing wastes. As discussed in Appendix A, LANL already has twenty-four standard designs to accommodate the variety of equipment to be housed.

This phase of the study has identified eight important issues for next-generation glovebox design modifications, as communicated to INEEL by LANL TA-55 personnel. The eight issues address possible modifications to:

- Lead shielding sandwich in the glovebox wall
- Window gasket seals
- Wall penetrations and feedthroughs
- Flange connector rings
- Sharp internal corners and other obstacles to cleanup
- Surface finish of internal surfaces
- Glove materials and locations of gloveports
- Lighting in gloveboxes.

During the next phase of this glovebox redesign task, the authors will closely examine these issues, research possible resolutions, perform an engineering survey, and recommend specific technical improvements.

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Appendix A - Standardized Glovebox Design Discussion

APPENDIX A - Standardized Glovebox Design Discussion

This Glovebox Design Enhancement task was directed to be a study of glovebox design and usage to recommend design enhancements for next-generation gloveboxes. Design enhancement includes modifications to existing facilities and new facility construction. A pollution prevention study on glovebox operations has been included in this task to identify and then reduce, the amount of waste streams generated by present and future gloveboxes when they are used and disposal costs of gloveboxes at their end of life.

Initially, a standardized glovebox design was requested as part of this task. Standardization would be useful and perhaps beneficial in some plutonium (Pu) handling applications, such as production oriented processes (i.e., Rocky Flats, etc.). Most of the glovebox processes at Los Alamos National Laboratory's (LANL's) Technical Area 55 (TA-55) plutonium handling site will not benefit from a single standardized design. The diverse, specialized nature of the operations at TA-55 include plutonium recovery using chemical processes, plutonium metal production, plutonium metal fabrication, plutonium heat source production, and advanced nuclear fuels fabrication [A-1]. This diversity means that a single standardized design is not feasible confinement for all processes. Such diverse activities as chemical processes and machine shop fabrication require individualized confinement barriers. LANL currently has 24 standardized shell configurations for gloveboxes, tailored to house the variety of equipment that must be confined [A-2]. For example, a glovebox housing a welder will require different accommodations and services than a furnace, a chemical reaction tank, or a waste bagout station. During a tour of PF-4 in June 1998, the authors noted that some of the gloveboxes have a single 'working deck' of operator workstations (that is, pairs of gloves at a given height from the floor), while other have as many as three decks; the upper decks being accessed by moveable stairs or ladders, depending on the operation housed within the glovebox and the maintenance requirements for that operation. Such volumetric variance is extremely difficult to standardize. LANL does meet the intent of the canceled DOE Order 6430.1A, where standardization of design features for enclosures was required. That DOE Order required standardized windows, gloveports, ease of interior glovebox cleaning, illumination, service line connections, fire barriers, filter installations, sample removal ports, pressure readouts, and glovebox interconnections. The glovebox system design description [A-3] shows that most of these features are already standardized at LANL and other features are standardized throughout the glovebox industry (for example, the American Glovebox Society guidelines [A-4]). The set of engineering drawings for LANL gloveboxes listed in Reference [A-3] also shows the standard features.

Another issue regarding standardized design is that while standardization promotes reduced capital cost, shorter fabrication times, and possibly easier process setup within the glovebox due to extra clearances, it can increase operational costs. A standardized glovebox would have to be reasonably large, simply because a small glovebox would not adequately enclose many of the operations at TA-55. The result would be that many other operations would have to use a glovebox much larger than necessary. Using large gloveboxes would create design problems due to overhead clearance for cranes and the trolley conveyor system used at PF-4. Also, operating large gloveboxes would be costly

because they would create more waste. For example, the waste gas handling and cleanup for inert atmosphere gloveboxes (usually five gas changes/hour) would be a higher volume, and there would be more frequent filter changeouts for air atmosphere gloveboxes (usually seven air changes per hour) because of the extra air volume that must be sent through the box. Since filters are treated to recover any plutonium trapped in them, the cost is more than just that of a filter and a few minutes of operator time for replacement. Large gloveboxes would mean the provision of more gloveports and extra panels for service penetrations for operational versatility. In many of the process applications these extra penetrations could lead to contamination control concerns because of the extra seals on each box even though the penetrations would be blank flanged when not used. The in-box fire protection systems (i.e., gas suppression or graphite powder suppression) would have to be sized to adequately protect the greater volume in the glovebox. Large gloveboxes would lead to higher operating costs in lighting, and somewhat higher power needs for fans and waste gas handling/cleanup equipment. The large size would not be optimum from an ergonomic perspective, since reaching and stretching to perform periodic housekeeping/cleaning of the glovebox interior would be quite laborious. Another important concern with a large standardized glovebox is that the building rooms can only accommodate a fixed number of these large footprint boxes, so if process segments require individual gloveboxes for containment (i.e., keep a furnace physically separated from a bath process by housing in different gloveboxes), then it could become difficult to fit the desired number of standardized gloveboxes into the existing facility. Typically, gloveboxes are designed to fit the building floor space provided, in a trade-off with space needed to house the process equipment in the box. Gloveboxes can be thought of as very expensive real estate, because they are costly - therefore the floor space and volume in the glovebox are well-used [A-5]. There is usually an influence on the designer to fit the gloveboxes into a small floor space: this can be due to the cost reduction in building construction or the need to make do with an existing building, the cost of the glovebox, and a requirement to reduce building surface areas for decontamination in case of a spill outside a glovebox. Gloveboxes also have a size restraint due to the operator's maximum reach distance (taken to be 28 inches depth at LANL) and how many gloveports are advisable to use on the glovebox.

While decontamination and decommissioning (D&D) lessons learned show that a standardized glovebox would be helpful for glovebox sectioning and disposal tasks [A-6, A-7], going to a standard size would produce extra volume of waste for disposal. Another D&D concern was the ability to easily assay each glovebox; when the boxes are too closely spaced this is difficult. Using standardized large size boxes, they would need to fit closely together at TA-55.

To summarize, the reasons to not pursue standardization of gloveboxes at LANL's TA-55 are: (1) specialized operations require specialized confinement barriers, (2) a large sized standard glovebox would create clearance problems in most of the rooms, (3) large gloveboxes are not as economical to operate over their lifetime as custom-sized units, (4) a large, standardized glovebox may not be ergonomically friendly, (5) there is great difficulty in fitting large gloveboxes to house process lines within existing facilities, and

(6) the end of life waste mass and volume would be larger for a large size standard glovebox than for smaller, specialized gloveboxes.

For the reasons discussed above, a single glovebox standardized design was not pursued in this task. However, as designers select glovebox features and options that have proved successful in the field and specify robust materials in box construction, the gloveboxes tend toward standardization at a certain level; that is, the gloveboxes may not all look alike but would all be constructed from stainless steel, use laminated glass windows, use the same filtration method, and use the same pressure monitoring instrumentation. It may be possible to produce a standardized set of design options (window materials, filters, glovebox shell materials, etc.) to use for the different operations at TA-55, but that task would be involved due to material chemical compatibility considerations and would require detailed information and access to the various processes in each wing of the PF-4 facility. A few of the possibilities for these 'design option sets' will be addressed in the course of the design enhancement task.

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**APPENDIX B - Compilation of Specifications for Gloveboxes
at LANL TA-55**

APPENDIX B - Compilation of Specifications for Gloveboxes at LANL TA-55

During the course of this glovebox design enhancement task, the authors reviewed documentation on glovebox design specifications for TA-55. The system design description [B-1] provides many design values. This list of design parameters is not complete, but it does give an overview of the glovebox design. Information presented in this appendix has been obtained from the system design description, from conversations with TA-55 staff, from conversations with fabricators, and by observations during facility tours.

Glovebox shell

Stainless steel 304 or 304L is used for dry process glovebox shells.
Stainless steel 316 or 316L is used for aqueous process glovebox shells.

7 gauge sheet (0.1793 to 0.1875 inches thick) is used for the glovebox wall.

When a stainless steel skin is needed over radiation shielding, 16 gauge (0.0598 to 0.0625 inches thick) or 11 gauge (0.1196 to 0.125 inches thick) is used.

The surface finish called out for the gloveboxes is the 2B mill finish for stainless steel sheets. A 32-microinch finish is required on all interior and exterior glovebox surfaces.

The shell must be finished with no crevices or corners, and all interior corners must be contoured with a minimum 0.625 inch radius to facilitate cleaning and decontamination.

Stainless steel is not painted.

Radiation shielding

Gamma or neutron shielding can be included when needed. Gamma shielding consists of a 0.25-inch-thick lead covering on the glovebox shell from the bottom of the box to roughly 6 feet from the floor. The lead is sandwiched between the glovebox shell and the skin. The lead should not be glued or otherwise attached other than having the skin over it.

Neutron shielding is 4% boron carbide, 2 inches thick, cast inside stainless steel cladding. This shield is overlaid with 0.25 inch of lead and an outer cladding of stainless steel. Water can be used in place of the boron carbide.

Windows

Viewing windows are laminated safety glass, at least 0.25-inch-thick. The window is mounted either by a spline gasket "zippered" mounting or by a bolted frame arrangement that compresses a gasket to seal the window.

Windows can be shielded by using 0.25- to 0.375-inch-thick leaded glass on the standard window for gamma radiation. For neutron radiation, standard windows are covered with polymethyl methacrylate (PMMA, also called Plexiglas) shielding.

Penetrations

Electrical power feedthroughs into gloveboxes are hermetically sealed using potted connections or other means. Unused penetrations are plugged inside and outside.

High efficiency particulate air (HEPA) filters

When the atmosphere in the glovebox is exhausted, it is filtered to prevent contamination of the ventilation system. Fire screens are also installed to protect the HEPA filters. The standard 8-inch-diameter filter system has one filter on line and one in reserve to facilitate changeout. During changeout, the filter canister is opened and a new filter is stacked atop the reserve filter, which pushes the on-line filter down into the glovebox for removal. The reserve filter moves into the on-line position and becomes the active filter. There are other HEPA filter sizes (12-inch diameter, 24-inch square, and others) for specialized applications in some gloveboxes.

Overpressure relief device

A bubbler unit is used to provide for glovebox overpressure relief when inert atmospheres are used, or on any glovebox that might overpressurize. The bubbler uses a manometer principle of internal pressure working against a column of silicone oil to prevent backflow of air into the inerted glovebox. When the internal pressure increases past the pressure in the oil column, bubbles of inert argon gas escape the bubbler. The gas is then filtered and stacked. The bubblers usually have a bypass valve to lower pressure if the bubbler unit cannot reduce pressure quickly.

Support stand

Each glovebox uses a support stand to position the box at a convenient working height (about 50 to 52 inches from the floor to the center of the first level gloveports). Support stands are typically made of A36 grade carbon steel, and are painted. The support stands are anchored to withstand operating basis earthquake events, and they are electrically grounded.

Gloves

A variety of glovebox gloves are used at TA-55. Some gloves must be leaded to protect the operator's hands from gamma radiation, while other gloves do not require such protection. Gloves can be made of Neoprene, Butasol, or hypalon materials. An inner plastic glove ring protects the glove at the high wear area where the glove enters the gloveport, and a gasket protects the glove from its connecting clamp. A new 'push-through' glove design from the Central Research Labs has been examined at LANL. In this design, the glove is connected to a push-through glove ring that seals to a specially designed 9-inch diameter glove port. When the glove must be changed, a new glove is used to push the old one into the glovebox. The new glove's ring seals around the port to provide contamination control. The gloves used at TA-55 are typically 30 mils (0.76 mm) thick and 30 inches long. Left and right hand molded gloves are used rather than ambidextrous molded gloves. Gloves are visually inspected daily and changed as needed.

Support systems

Gas supplies to operate in-box equipment must have pressure regulating valves set to less than 25 psi gauge, and the gas service lines are limited to 0.375-inch diameter as a protection against overpressurizing the glovebox. The supply line diameter is set based on the capacity of the ventilation system to evacuate the glovebox in case of a gas line breach in the glovebox. The supply lines are fitted with pressure instrumentation linked to solenoid shutoff valves. Instrument air lines can be operated at higher than 25 psi gauge.

When needed, vacuum pumps plumbed to gloveboxes use metal piping, and exhaust is routed to filtration.

Cooling water for in-box processes is carefully controlled to avoid nuclear criticality events. Positive Pressure Chilled Circulating Water (PPCCW) systems cannot be used in gloveboxes. Limited Volume PPCCW (LV-PPCCW) systems can be used in a sealed cooling loop within a glovebox, since limited volume means that the available water that could potentially leak into the box cannot result in a criticality or a glovebox overpressure event. Negative Pressure Chilled Circulating Water (NPCCW) systems can be used inside gloveboxes.

Tubes, piping, or conduits are routed away from the face of the glovebox to keep that area clear for the operators.

Ventilation systems operate to keep the gloveboxes at -0.6 inch of water with respect to the room. Dampers are used to set up the flow through the glovebox to achieve the required pressure. Once the dampers are set, they are generally left in that position. Pressure gauges faces are arranged to face the front of the gloveboxes. Magnehelic pressure gauges are used on air atmosphere gloveboxes, these are just a local readout of pressure. Photohelic pressure gauges are used on inert atmosphere gloveboxes, they control the argon inlet and outlet valves to the glovebox [B-2].

Heat sensors are mounted near the top center of the gloveboxes.

Lighting is strategically placed outside windows in the glovebox ceiling. In some cases, additional lighting may be placed inside the glovebox.

The minimum electrical requirements for a drop box are one 115 Volt duplex outlet. Double or multiple section drop boxes have two 115 Volt duplex outlets.

Appendix B - References

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